RHEOTROPISM OF EPINEPHELUS STRIATUS BLOCH

By Hovey Jordan

BERMUDA BIOLOGICAL STATION FOR RESEARCH, AGAR'S ISLAND, BERMUDA[1]

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An unusual, but orderly, arrangement displayed by several groupers or hamlets (a marine fish, *Epinephelus striatus* Bloch), confined in a cage through which flowed a current of fresh seawater, called my attention to their peculiar rheotropism. The tails of all were directed *into* the current. When this was shut off their arrangement became promiscuous, indicating that their novel posterior orientation was a true rheotropic response.

This phenomenon led me to investigate in detail the behavior of these fishes both in groups and individually, in order to determine whether this posterior orientation to a current—which, so far as I have been able to learn, is undescribed—is a normal response of the grouper. For this purpose a number of fishes were placed in the cage and a record was made of the positions which they assumed at two-minute intervals. These observations were made both at night and during different parts of the day. In one record, which is fairly typical, the positions of each of 7 fishes at 30 successive intervals—in all 210 observations—were noted. Of the 210 observations 141 showed the fishes to be tail into the current (posterior orientation), 67 side to the current (lateral orientation), and only 2 head into the current (anterior orientation). In order to determine whether posterior and lateral positions indicate different responses by individual fishes, or are simply phases of one reaction, fishes were studied singly. For this I used a small aquarium (30×20 inches) across which a moderate current of water flowed diagonally. Each of the fishes tested remained most of the time near the inlet in the region of the strongest current. It assumed in succession slightly different positions, chiefly by rotating the long axis of the body through an arc of 90° to 180° around its own center, which preserved a comparatively fixed position in the axis of the current, so that either one side of the body or the tail was at any given instant directed toward the current, into which, however, the head was never pointed. After assuming approximately a dozen such temporary positions, which required about three or four minutes, the grouper tailed directly into the current and remained in this position for about three minutes. It then began a second series of changes similar to the first. In this sequence of positions it is perhaps most natural to regard as a single

period the time occupied from the beginning of one set of 'swinging motions' to the beginning of the next; thus the posterior orientation, which is of longest duration, is the last phase of the orienting process. A characteristic reaction, then, of *Epinephelus striatus* is posterior or lateral orientation to a current. Since in a majority of cases the orientation is posterior, and since this is maintained longer than any other position, it is a fair inference that this is the significant reaction.

Various regions of the body were explored with a localized current (1/28 liter per second) directed through a long glass tube, the experimenter being invisible to the fish. The following areas were found to be sensitive, but the response varied in promptness. Stimulation of the lips (if prolonged it causes a relatively violent reaction) brought forth a response in 7 seconds; the caudal fin in 16 seconds; the dorsal fin in 22, the cheek and operculum in 25, and the side of the body in 30 seconds. From these observations it is clear that the lip region is much the most sensitive part of the surface of the body, and the possibility is at once suggested that the posterior orientation of the fish is a reaction which serves to protect this region from the action of the current. This seems the more probable from the fact that prolonged stimulation of this region by the current employed in the experiment always caused a rather extraordinary and violent reaction.

Several end organs have, at one time or another, been regarded as the receptors in the case of rheotropic responses: lateral-line organs[5] (Schulze, '70); the organs concerned in response to pressure[7] (Verworn, '97, p. 445ff., barotaxis), and the ear[6] (Tullberg, '03).

Two other views have been advocated, first, that it is the tactile corpuscles which are stimulated by currents[3,4] (Parker, '03a, '03b); secondly, that it is chiefly the eyes which are stimulated, this being due to the transportation of the fish through the water. According to this view[2] (Lyon, '04), rheotropic reactions are chiefly optic reflexes, which serve to compensate the apparent motion of the visual field. This is an indirect effect, a direct stimulation being produced only when the fish is in contact with some part of the solid environment. This, in the case of blind fishes, Lyon thinks acquaints the animal with its transportation and a compensatory swimming results.

In studying the question of rheotropic end organs, observations—to be described elsewhere—were made which confirm the idea that sense cells of pressure and equilibration are unaffected by water currents. The lateral-line organs and the eyes, which can be rendered functionless by appropriate operations, are also unaffected. The skin was next removed from certain body areas and the underlying tissue was

found to be insensitive to localized currents. This indicates that the rheotropic end organs are cutaneous; of these only the tactile corpuscles were found to be of significance. This is shown by the following experiments. Under normal conditions stimulation of the lips by a glass rod produces a very violent negative reaction, and so, too, does a current of water of the sort just described. The lips of a normal fish were anaesthetized by the application of a 0.1% solution of cocaine. As a result the reaction (and assumably the sensitivity) to tactile stimulus disappeared completely, and also the reaction to the water current. Not only that, but also the parallelism between the effects of the two sorts of stimuli at any instant, both during the gradual benumbing of the lips by the reagent and during their progressive recovery from insensitivity, seemed to be complete. These facts indicate that the end organs of tactile sensitivity serve also as the essential and organs of rheotropic sensitivity. Other sensory cells, while they may in some cases be affected by currents, apparently play no necessary part in the reaction here described.

[1] Contributions from the Bermuda Biological Station for Research, No. 56.
[2] Lyon, E. P., *Amer. J. Physiol., Boston,* **12,** 1904, (149–161).
[3] Parker, G. H., *Washington, D. C., Bull. U. S. Fish. Com. for 1902,* 1903, (45–64).
[4] Parker, G. H., *Amer. Nat., Boston,* **37,** 1903, (185–204).
[5] Schulze, F. E., *Arch. mikr. Anat., Bonn,* **6,** 1870, (62–88), Taf. 4–6.
[6] Tullberg, T., *Vet.-Ak. Bih., Stockholm,* **28,** 1903, (No. 15, 25 pp.).
[7] Verworn, *Allgemeine Physiologie,* 2te Aufl., 1897, (xi + 606).

STUDIES OF THE GENUS PHYTOPHTHORA

By J. Rosenbaum

BUREAU OF PLANT INDUSTRY, WASHINGTON, D. C

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Although the actual number of species of Phytophthora is small, geographically they are very widespread, their presence having been recorded from the tropics as well as the temperate regions.

The morphological similarities between the different species, together with the great variation in the same species make the identification and separations of the species belonging to this genus exceedingly difficult. With a view to remedying this situation and determining characters of diagnostic value, nine out of the eleven described species were collected, grown in pure culture on artificial media, and studies made from a systematic and biometrical standpoint. It was not possible to procure material of *P. thalictri* and *P. colocasiae.* The following is a list of the cultures used: